CORRESPONDENCE

Comments on "An Evaluation of Certain Forms of Momentum Transfer in the 26-Month Oscillation"

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In his opening paragraph Professor Staley [2] states that although inferred as being important, no correlation between zonal and meridional wind fluctuations have so far been detected in the lower stratosphere over equatorial regions. I should like to point out that a study of wind observations in these regions *has* yielded positive results, and that these have been used in a non-Fickian treatment of the zonal eddy flux in the momentum balance equation (Tucker [3, 4]). If the zonal wind oscillation is given by

$$U(z, t) = A(z) \sin\Psi(z, t)$$

where A is the amplitude of the oscillation and Ψ its phase angle, it was shown that the divergence of horizontal eddy flux of momentum can be represented by

$$\frac{\partial}{\partial y}\overline{v'u'} = B(z) + C(z) \sin[\Psi + \phi] \qquad (1)$$

B lies close to zero, observations suggest a form for $C(z)$, and the phase difference ϕ between U and $\frac{\partial}{\partial y}\overline{v'u'}$ is approximately $\pi/2$

In the second paragraph it is implied that the treatment by Reed [1] represents a fully acceptable description of the meridional and vertical fields of motion. Yet Reed's treatment depends entirely on a Fickian approach to the large-scale horizontal flux of heat. In the same paper Reed has stated that a similar approach to the momentum flux is inapplicable; Staley also comes to the same conclusion. This apparent discrepancy between the approach to two different parameters is all the more important because it has been shown (Tucker [3]) that if the horizontal convergence of northward eddy flux of momentum is represented by equation (1), then such a non-Fickian treatment yields a kinematic scheme in which vertical velocity is invariant in time, provided that the vertical eddy viscosity is also invariant in time. This result is quite different from that obtained by Reed who derived vertical velocities with a 26-mo. period, oscillating about zero.

This brings me to the third point. Staley has assumed that, in his symbolism, QK_{mz} is constant with height. But in a theoretical treatment of the momentum balance equation (Tucker [3]) it has been shown that the form of $QK_{mz}(z)$ is very closely related to $\frac{\partial}{\partial y}\overline{v'u'}$. One of the topics at present being investigated is the form of $QK_{mz}(z)$ most consistent with the value of $C(z)$ in equation (1). Thus Staley's assumption is not as innocuous as it appears.

It might be appropriate at this stage to say a little more about the form assumed for the vertical dynamic eddy viscosity QK_{mz}. The three treatments by Reed, Staley, and Tucker have each taken the vertical exchange coefficient to be invariant in time. Since the lower stratosphere is characterized by a marked hydrostatic stability, free convection of the type experienced in the troposphere can play no part in the interchange of air between different levels. However, there is a possibility that forced convection may be important in this region. It has already been mentioned that large scale horizontal eddies have been shown to play a major part in horizontal momentum divergence; it is reasonable to suppose that they *may* also be associated with horizontal mass divergence and thus with the vertical interchange of air. If this occurs then a 26-mo. oscillation in the value of the dynamic eddy viscosity must be considered. In Tucker's treatment this would affect the constancy in time of the derived vertical velocity which would become oscillatory.

REFERENCES

1. R. J. Reed, "A Tentative Model of the 26-Month Oscillation," *Quarterly Journal of the Royal Meteorological Society*, vol. 90, No. 386, Oct. 1964, pp. 441–466.
2. D. O. Staley, "An Evaluation of Certain Forms of Momentum Transfer in the 26-Month Oscillation," *Monthly Weather Review*, vol. 93, No. 3, Mar. 1965, pp. 157–162.
3. G. B. Tucker, "Zonal Winds Over the Equator," *Quarterly Journal of the Royal Meteorological Society*, vol. 90, No. 386, Oct. 1964, pp. 405–423.
4. G. B. Tucker, "The Divergence of Large Scale Horizontal Eddy Flux of Momentum in the Lower Equatorial Stratosphere," *Quarterly Journal of the Royal Meteorological Society*, vol. 91, No. 389, July 1965, pp. 356–359

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Reply

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Dr. Tucker's first point is that wind observations have shown correlation between zonal and meridional wind components in the lower stratosphere over equatorial regions. Neither of the two references that he cited to his

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